



Air Traffic Management (ATM) Technology Demonstration - 1 (ATD-1): Terminal Sequencing and Spacing (TSAS) and Flight Deck Interval Management (FIM)

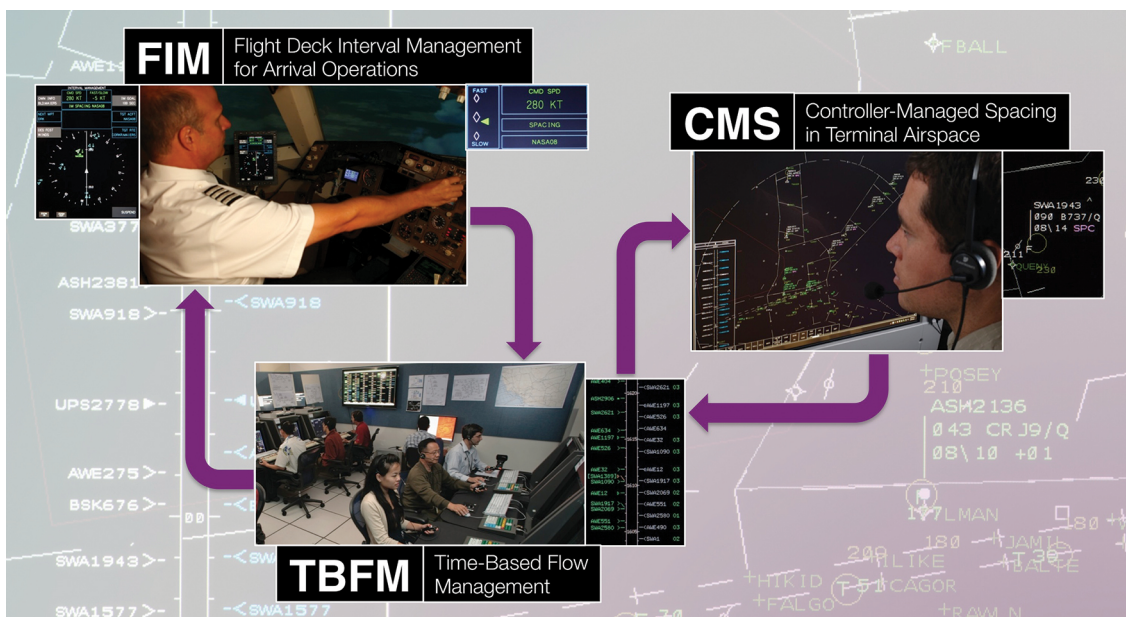
Today's National Airspace System

In 2014, the U.S. National Airspace System (NAS) managed the progress of nearly 10 million flights. During peaks of airspace operations, there are thousands of commercial aircraft in flight, many concentrated over key metropolitan areas. With such high air traffic demand, airspace operations are not always the most efficient or coordinated, often due to the persistence of operating procedures that have largely remained unchanged from the earliest days of commercial aviation. As a result, the air transportation system often experiences unnecessary delays and lost productivity, and produces greater amounts of noise pollution, carbon dioxide, and other greenhouse gas emissions than if operations were more efficient. As air traffic demand is projected to grow over the next

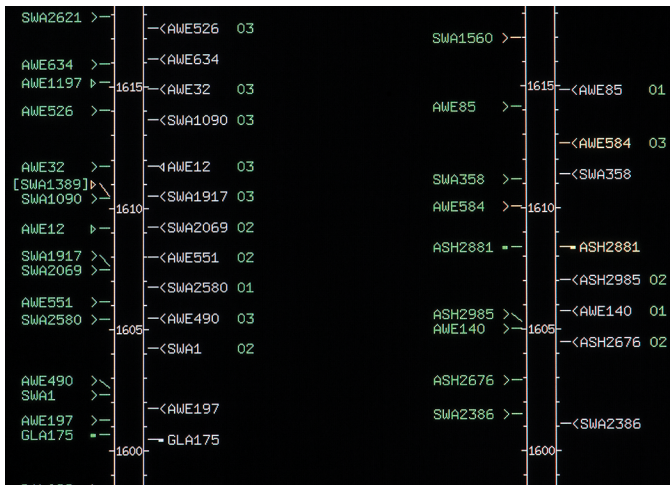
two decades, our current air traffic control system will be further strained and the environment adversely affected.

Improving the efficiency of the terminal area, which is the volume of airspace surrounding airports to a radius of about 50 miles, is an especially complex task due to operating characteristics that are quite distinct from the en route environment. Terminal area controllers manage both ascending and descending aircraft, more frequent turns, a wider range of separation standards, as well as terrain and increased traffic density within shorter time horizons.

In today's terminal area arrival operations, as an aircraft transitions for landing, controllers track and guide the aircraft from cruise altitude to the runway using simple visual aids as well as their skills and judgment.



ATD-1 is the integration of three NASA technologies that provide a coordinated solution for managing arrival aircraft from just prior to their top-of-descent and continuing down to the runway.



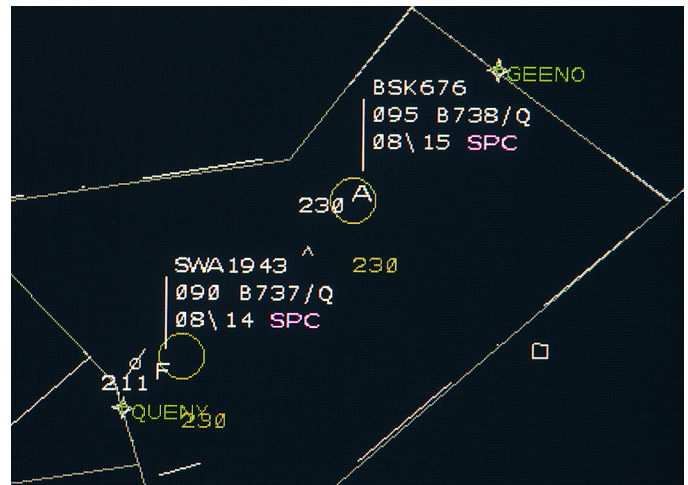
Time-Based Flow Management (TBFM) determines an arrival schedule that increases use of more direct arrival routes for safe, orderly, and expeditious flow of traffic in the terminal area.

They issue turn-by-turn instructions (a process known as vectoring) via radio communications. As aircraft approach the runways from different directions, controllers manually merge aircraft and sequence them for arrival. Busy terminal area conditions often force the aircraft to fly inefficient arrival paths involving frequent changes in direction, altitude, and speed to maintain safe separation from other aircraft. Frequently, controllers must employ longer routes (known as path stretching) or holding patterns to tactically accommodate larger amounts of delay. The tactical nature of this manual approach leads to increased fuel burn and noise pollution, contributes to high controller workload, and exacerbates traffic congestion. Moreover, the imprecision of this current system creates greater uncertainty, and forces controllers to add buffers to the separation required between aircraft, which decreases airspace capacity, leading to further delays.

While more efficient arrival paths are achievable today, current technology limits their feasibility to periods of light traffic conditions, such as during the middle of the night. During periods of high-density traffic, maintaining safe separation and throughput takes precedence over achieving efficient operations. The technical challenge facing the aviation community is to make efficient arrival procedures common practice during heavy traffic when they are needed most, while still ensuring safety and throughput.

NextGen: The Airspace System of the Future

NASA is collaborating with the FAA and industry partners to develop several advanced automation tools that provide air traffic controllers, pilots, and other airspace users with more accurate real-time information about the nation's traffic flow, weather, and routing. The greater precision of this information is a key enabler



Controller Managed Spacing (CMS) tools provide controllers with the information needed to precisely space all aircraft to meet terminal metering schedules.

of the Next Generation Air Transportation System (referred to as NextGen). NextGen is a comprehensive transformation of the NAS, which will be safer, more reliable and more efficient, and will reduce the impact of aviation on the environment. The transition to NextGen is vital to improving system performance, meeting continued growth in air traffic, and increasing the nation's mobility to support economic progress.

NASA is developing an integrated set of NextGen technologies, called ATM Technology Demonstration-1 (ATD-1), that provides an efficient solution for managing arrival aircraft beginning from just prior to top-of-descent and continuing down to the runway. The ATD-1 suite of technologies has been tested separately, and each has demonstrated benefits in throughput, delay, and fuel-efficiency. Together, the technologies demonstrate the feasibility of high throughput of efficient arrival operations during peak traffic conditions in the terminal area. Simply put, the integration of these terminal arrival tools will allow arrival aircraft to safely fly closer together on more fuel-efficient routes to increase capacity, and reduce delay, fuel burn, noise, and greenhouse gas emissions. Moreover, with ATD-1 technologies, both pilots and controllers will have more accurate and timely information and advisories, thus reducing the need for extensive coordination and negotiation between them to achieve more efficient operations and alleviate controller workload.

Instead of tactically absorbing delay close to the airport, where it is traditionally handled using path stretching and holding patterns, subtle variations in speed are applied from cruise altitude to landing to distribute small amounts of delay still required over a longer portion of the flight. Strategically absorbing delay in this way relieves congestion that would otherwise build up near the airport, further increasing the efficiency of terminal



Flight Deck Interval Management (FIM) tools aboard the aircraft enable flight crews to precisely space their aircraft relative to others to achieve ideal spacing.

area traffic flows. The more orderly, precise, and direct traffic flow enabled by the ATD-1 technologies will make the NAS more predictable overall. This allows airspace users to better respond to unexpected delays caused by convective weather and other airspace constraints.

ATD-1 technologies include:

- Time-Based Flow Management (TBFM)
- Controller Managed Spacing (CMS)
- Flight Deck Interval Management (FIM)

Time-Based Flow Management (TBFM) generates a conflict-free arrival schedule based on airport conditions, airport capacity, required spacing, and weather conditions. The schedule increases use of the FAA's Performance-Based Navigation (PBN) arrival procedures, which use more direct routes that extend from en route airspace and continue through terminal airspace to the runway. Arrival scheduling involves metering of traffic flows in the terminal area to ensure that aircraft merge smoothly from different directions and avoid downstream congestion that would otherwise prevent them from flying efficient flight paths. The schedule is determined well in advance of execution and it is communicated to controllers at both Air Route Traffic Control Centers (ARTCC) and Terminal Radar



The higher precision achieved by ATD-1 technologies will reduce the size of excess spacing buffers, resulting in higher terminal throughput and capacity.

Control (TRACON) facilities. Flight crews know their intended flight path, which aircraft they ought to be following, and the desired spacing interval at critical points along their designated PBN route to reach the destination airport safely and on schedule. Controllers no longer have to make as many tactical interventions concerning merges and arrival slots, with short time horizons, relative to today's operations.

Controller Managed Spacing (CMS) decision support tools provide controllers with the information needed to precisely space aircraft at merge points using speed adjustments instead of vectoring. CMS enhances the controller's current display with textual and graphical representations of the terminal arrival schedule created by TBFM to indicate where an aircraft is expected to be along its PBN route, and calculates the speed advisories needed to maintain this schedule. Thus, controllers have advisories to help prevent congestion near the runway and continue use of PBN procedures during heavy traffic conditions.

ATD-1 also has advisory tools targeted for the pilots. It is anticipated that some aircraft will have sophisticated onboard avionics that enable pilots to maintain their own spacing to achieve the TBFM schedule. In lieu of speed instructions from controllers, the Flight Deck Interval Management (FIM) capability provides speed guidance to pilots to precisely maintain an aircraft's spacing behind another aircraft. These speed advisories use information provided by Automatic Dependent Surveillance - Broadcast (ADS-B) technology aboard the aircraft that is more accurate than traditional radar. Flight crews are able to make finer adjustments to their speed and react more quickly to achieve the necessary spacing. With further TBFM support, the tighter control enabled by FIM is expected to reduce excess spacing between aircraft, resulting in higher airport throughput.

Steps to Achieving NextGen

The ATD-1 system has been evaluated in a series of high-fidelity human-in-the-loop simulations to mature the technologies towards operational use.

The FAA refers to ATD-1's ground automation tools (i.e., TBFM and CMS) as Terminal Sequencing and Spacing, or TSAS. From 2009-2015, twenty-five high-fidelity human-in-the-loop simulations were conducted by NASA to mature TSAS from proof-of-concept design to a demonstration prototype. Arrival procedures at several airports in the United States were simulated (using active and retired controllers with extensive operational knowledge) to gain experience with a broad range of traffic demand scenarios and wind conditions. NASA and the FAA also conducted an operational integration assessment of TSAS with current FAA NextGen hardware and software to reduce the risk in operational implementation.

The simulations initially focused on the integration of the various TSAS components, and were followed by simulations to refine the TSAS concept of operations in response to controller feedback. The final simulations evaluated the performance, controller acceptability,

and operational integration of a demonstration TSAS prototype. Results from simulation testing of TSAS were favorable, overall demonstrating markedly increased PBN utilization by controllers and modestly improved spacing accuracy without increased workload.

Demonstration prototypes of the TSAS tools were transferred to the FAA in 2014 for further testing and evaluation, and the final technology transfer package is planned for December 2015. TSAS is targeted for deployment to several busy airports in the United States beginning in 2019. NASA will continue providing technical support throughout the remaining phases of deployment.

ATD-1's airborne and ground automation for FIM is also referred to by the FAA as Interval Management — Arrivals, Approaches and Cruise (IM AAC), which is the first instantiation of IM based on arrival, approach and cruise operations to independent runways in an environment preceding data communication. NASA has tested the FIM capability in eleven laboratory simulations of increasing capability and maturity, leading to a flight demonstration on board the Boeing 787 EcoDemonstrator in December 2014. The flight demonstration served as a proof-of-concept flight test to assess the risks associated with FIM flight operations involving two or more coordinated aircraft. The latest version of the FIM algorithm, known as Airborne Spacing for Terminal Arrival Routes (ASTAR), supports RTCA-based industry standards for the FIM system and it is being used as the basis for avionics prototyping efforts to build, test, and fly the ATD-1 FIM system.

NASA is collaborating with industry partners to develop prototype flight hardware and software based on ASTAR, and install the system on two test aircraft for further evaluation in a flight test planned for early 2017. NASA plans to transfer the prototype FIM system and all associated products to the FAA for further testing by 2018.

For more information on ATM Technology Demonstration-1, please visit

www.aviationsystems.arc.nasa.gov

Benefits of ATD-1's Integrated Terminal Area Scheduling Technologies

System Benefits

- More orderly flow of terminal area traffic
- More efficient handling of delay
- Better situation awareness
- Reduced excess spacing buffers
- Increased throughput
- Decreased controller workload

User Benefits

- Increased use of advanced PBN arrival procedures
- Greater fuel-efficiency
- Fewer delays

Environmental Benefits

- Fewer greenhouse gas emissions
- Less noise pollution

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